Environmental Health Perspectives
Vol. 44, pp. 165-174, 1982

A Study of Acute Respiratory Disease in Families Exposed to Different Levels of Air Pollution in the Great Salt Lake Basin, Utah, 1971-1972 and 1972-1973

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The reported incidence of acute respiratory illness in families exposed to different concentrations of air pollution was studied during two consecutive school years. The purpose of the study was to determine the effect of increased exposure to sulfur dioxide and suspended particulate matter. In each of four study communities, the mothers of approximately 250 white families were contacted biweekly to obtain information regarding the occurrence of respiratory symptoms in each family member. Annual mean ambient sulfur dioxide concentrations in one community for the three years included in the study (1971-1973) were well above the current air quality standard of 80 $\mu g/m^3$, while in the other three communities the annual sulfur dioxide concentrations were much lower (usually less than 40 $\mu g/m^3$). Suspended particulate matter concentrations in the high sulfur dioxide community were close to the limit designated by the annual standard (75 $\mu g/m^3$) but actual exposures in the four communities probably were not excessive. Regression analyses of the data collected showed inconsistent associations between illness rates and educational attainment of the head of household, crowding in the home, bronchitis in parents or smoking by parents. However, once the effects of these factors were removed the adjusted rates showed little association with community of residence. It was concluded that the higher concentrations of sulfur dioxide in the Utah atmosphere could not be the cause of increases in acute respiratory illness in the exposed populations.

Introduction

The occurrence of acute respiratory illness in populations exposed to differing concentrations of air pollution was studied in Utah during the 1971-72 and 1972-73 school years. The studies conducted by the Health Effects Research Laboratory of the U.S. Environmental Protection Agency were undertaken in an effort to provide additional information relevant to effects of exposure to atmospheric sulfur dioxide (SO_2) and suspended particulate matter (TSP).

A number of studies related to this subject have been reported from the United States and from England (*1-14*). These have been consistent in their findings of higher incidences of lower respiratory illness in populations exposed to relatively high concentrations of ambient air pollution. Less consistently, upper respiratory illness also has been associated with such exposure. At least some of these studies also demonstrate the effect of socioeconomic factors on respiratory illness rates (*12*, *13*).

A retrospective study of lower respiratory illness in the same study areas in Utah (*15*) found that children who had resided in the high pollution area for three years or more had more illness than did their counterparts in the less polluted communities. However, no association between pollution exposure and illness was found for children with residence times of less than three years. The prospective studies reported here were designed to investigate whether higher rates for acute respiratory disease (ARD) persisted in the high pollu-

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tion area or if the lack of association in shorter term residents reported earlier (*15*) was indicative of an improving health status. Since the time of the study, there have been indications that some of the measurements, particularly those for TSP, may have been subjected to a consistent negative bias in the range of 10 to 30% (*16*). For the current report, therefore, a comparison has been made of data collected by the USEPA with other data collected independently at the same or similar sites by the State of Utah.

The study investigated a single hypothesis that the incidence or severity of acute respiratory illness was associated with the concentration of air pollutants to which populations were exposed. In addition, the effects of the more significant covariates on the illness rates were investigated. These include socioeconomic factors, smoking and the presence of chronic bronchitis.

Although analyses and presentation of these data have been delayed longer than usual, the information is relevant today because air quality standards continue to be a topic of controversy and because pressures to reduce the U.S. dependence on foreign sources of oil make it imperative that all information available relative to the possible impact of increased use of native coal supplies be reviewed.

Materials and Methods

Setting and Study Population

Four Utah communities, Magna, Kearns, Salt Lake City and Ogden, were selected for study on the basis of previously available aerometric and meteorologic data and similarity of socioeconomic status. The Utah setting was selected because past data suggested that a pollution gradient for SO_2 could be studied in a situation in which TSP was rather uniformly low. Magna was selected as the high pollution area, Ogden as the low pollution area and Kearns and Salt Lake City as intermediate areas. Families within each area were recruited from those responding to a chronic respiratory disease (CRD) questionnaire provided to every family that included an elementary school child. Since response was very good (approximately 95%), the candidate population was considered to be representative of families headed by younger adults with children attending elementary school. Each candidate family was contacted by an interviewer who completed a questionnaire concerning demographic characteristics whenever agreement for participation was given. Again, the refusal rate was low (estimated grossly by the investigators to have been <5%) and the sample enrolled was considered to be representative of that segment of the local population.

Interviewers, whenever possible, had had previous experience with telephone interviews. They were, in addition, given 2 or 3 days of intensive training to minimize interviewer bias. Interviewers were rotated routinely among the study subjects to maintain as much consistency as possible.

Approximately 250 families were recruited in each study area. The only restricting criteria when selecting families were that they must live within 1.5 miles (about 2.4 kilometers) of the air monitoring station; have lived in the home at least one year; have no plans to move within the subsequent year; have at least one child attending the local elementary school; and have a functioning telephone within the home. Families reporting substantial occupational exposure to dust by the head of the household also were excluded as were any individuals reported to have asthma, heart disease or chronic lung disease. These exclusions were made because of the potential confounding that could be associated with their inclusion.

The selection procedures limited the study populations to elementary school children and their immediate families. The incidence of illness was compared among these similar populations. It was not intended that the study populations should be representative of the total populations living in the various study communities.

Illness Monitoring

A telephone contact at biweekly intervals was made to each family to obtain information on illness experienced during successive two-week study periods. Specific information requested pertained to: the occurrence of any illness; fever; respiratory illness; restricted activity; and whether a physician had been contacted either in person or by telephone. If possible, the information was obtained from the mother or female guardian. If the mother was not available (estimated to have been < 2% of families, although not adequately documented), the information was obtained from whoever was considered to be the most responsible resident in the home.

Upper respiratory tract disease (URD) classification was given to illnesses whenever reported symptoms were limited to dry cough, head cold, sore throat, sinus or postnasal drip or runny nose. Lower respiratory disease (LRD) classification was given whenever the reported symptoms included chest cold, productive cough, asthma, croup, bronchitis or pneumonia.

The inquiry concerned asthma rather than wheezing because it was believed that among the population studied it would be better understood. Since individuals who on the initial questionnaire were identified as asthmatic were eliminated from the study, it is not believed that this question could have introduced a serious bias.

On a single occasion, a sample of the population was reinterviewed to determine the reliability of the data obtained by this telephone method. However, in no instance was confirmation by a physician obtained for the presence or absence of illness.

Monitoring Air Pollution Exposure

A single EPA air monitoring station was located in each study area. In Magna and Kearns the stations were atop one story buildings in 1971-72 but were moved to ground level at the same site for the 1972-73 study. In Ogden and Salt Lake City, the stations were at ground level during both years; however in both cities the monitoring site was shifted between 1971-72 study and the 1972-73 study a distance of about 0.5 miles to eliminate pollution generated by intense automobile traffic. Air monitoring data were collected during the same two year period by the Utah State Division of Health with monitors located at the 1971-72 EPA sites. These additional data provided a means of comparison in both years. At each station, 24-hr SO_2 measurements (West-Gaeke) and 24-hr high-volume particulate collections were made. Concentrations of water-soluble sulfates and water-soluble nitrates were obtained by laboratory analyses of the TSP collected. Nitrogen dioxide (NO_2) was monitored by the Jacob-Hochheiser method from 1970 to 1973.

Data Analysis

Data were analyzed for each year separately. Individuals reported on the initial interview to have asthma or heart or lung disease were excluded from the analyses, as were mobile families, defined arbitrarily as those living in the same residence for less than five years. Analyses were limited further to the white families since the percentages of nonwhites varied from area to area. Then only families who participated for one-half or more of the 15 study periods the first year or 16 study periods the second year were considered in the analyses. Comparisons were made among the three communities of illness rates per 100 person weeks of observations for fathers, mothers, and preschool (age 0-5 in 1971) and elementary (age 6-12 in 1971) school children. Repeated illnesses refer to separate events and not to continuing illness reported during two consecutive periods. Illness ratios were derived for each individual as:

$$\frac{\text{No. illnesses of a specific category reported}}{\text{No. weeks of participation}} \times 100 = \begin{array}{c}\text{Illness rate per}\\ \text{100 person-weeks}\end{array}$$

Each individual had three rates as disease indicators: upper respiratory illness rate, lower respiratory illness rate, and total respiratory illness rate. These individual illness rates were used as the dependent variable in multiple linear regression analyses.

Illness rates for groups were obtained by averaging the illness rates for all individuals within the group. Statistical significance of the group differences were determined by standard t-tests. The average severity of illness based on fever, number of days restricted activity, and the percent of illness prompting physician visits also were compared.

Other factors that might affect the incidence of respiratory illness were considered in the analyses. These included smoking habits of parents, crowding, educational status and bronchitis in parents. The importance of these factors was assessed by way of stratification and by the use of multiple linear regression analysis.

In the multiple regression analysis, a square-root transformation was made for the illness rates to meet more adequately the statistical assumptions. Analysis of variance tables were constructed to evaluate the effect of independent variables on the illness rates. Some interaction terms also were examined for their significance. These variables were tested by the sequential F test, with the community effect as the last variable to be entered in the model. The other variables were entered in the following order: education of the head of household, crowding, smoking, bronchitis, smoking + bronchitis and smoking + crowding.

The distribution of illness rates are inherently skewed to the left. However, the analysis of variance developed by the multiple regression method used is robust because a Fixed Effect Model was adopted and the sample sizes for the communities were large and approximately equal (*17, 18*). The square-root transformation reduced any effect due to tail-end cases.

Results

Air Pollution Exposures

Indications of the quality of the SO_2 and TSP data were obtained by comparing those collected by

EPA with those collected by the State of Utah. The comparison for SO_2 measurements suggested that while there were variations in the annual means determined, there were no consistencies with regard to the direction of the variations. Thus it was concluded that the approximate annual mean ambient concentrations of SO_2 were expressed equally well by either set of data. In addition, the moving of the EPA monitoring stations in Ogden and Salt Lake City did not effect significantly the level of agreement, although the differences decreased in Ogden and increased in Salt Lake City. In both Ogden and Salt Lake City, however, the measured levels were close to the minimum level detectable by the technique used.

Annual mean TSP values from the EPA monitors usually were lower than those determined by the state. The differences were greatest in 1971 and may represent a greater variability during the early phases of the EPA monitoring program. In all areas the annual means for 1972 from the EPA data were approximately 10 percent below those from the state. However, in 1973, the relocating of the EPA monitoring stations in Ogden and Salt Lake City to avoid the effects of high traffic densities had a significant effect on TSP measurements. Subsequent to the move, the annual mean TSP concentrations measured at the EPA monitoring sites in Ogden and Salt Lake City were 30 to 35% lower than those recorded by the state. Because the measurement best representing actual ambient exposure could not be determined, the higher value (state or EPA) for each community in each year was used to estimate exposure (Fig. 1). This presentation is least conservative and probably exaggerates the TSP exposures in Salt Lake City and Ogden.

The measured concentrations of SO_2 (West Gaeke method) showed a consistent difference across the study communities for the years 1971 to 1973 (Fig. 1) with Magna being high and the other communities relatively low. Daily data not presented in the figures show that the relative differences in exposure were consistent throughout the year. The 24-hr ambient air quality standard for SO_2 (240 $\mu g/m^3$) was never exceeded in Ogden or in Salt Lake City. The standard was exceeded infrequently during November, December, and January in Kearns and was exceeded with regularity during these months and infrequently during the remainder of the year in Magna.

Daily mean TSP concentration varied less. Measurements in excess of the 24-hr standard (260 $\mu g/m^3$) were recorded during the first or last quarter of the year in Ogden and Salt Lake City on more than 5% of the days, when collection were made adjacent to a busy roadway. The data indicated that

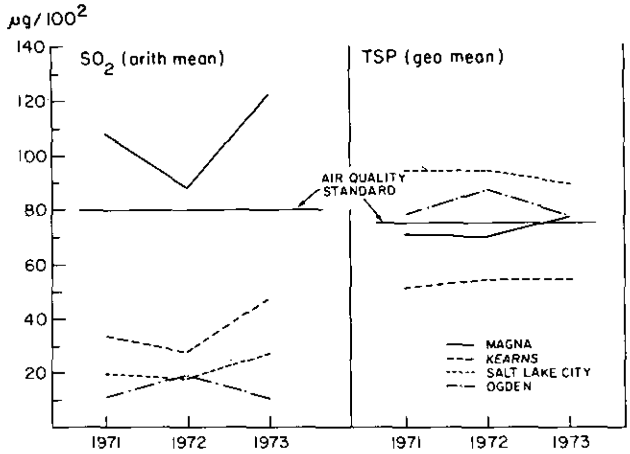

FIGURE 1. Concentrations of TSP and SO_2 in Utah study communities 1971-1973.

TSP concentrations were highest in Salt Lake City and lowest in Kearns. After the EPA monitors in Ogden and Salt Lake City were moved to residential sites comparable to those in Kearns and Magna, both the annual and the quarterly data indicated that TSP concentrations were highest in Magna and lowest in Kearns. These data suggest that the annual mean concentration in the study area may have ranged from about 75 to 110 $\mu g/m^3$ and that the daily standard was exceeded rarely.

Nitrogen dioxide (NO_2) measurements by the Jacob-Hochheiser method are considered to be unreliable. However, in 1974 NO_2 was measured by the arsenite method, which gave the same relative concentrations among the study areas and almost the same numerical levels. These suggested that annual mean concentrations of NO_2 were only 0.2 to 0.5 the annual ambient air quality standard (100 $\mu g/m^3$), but that concentrations probably were highest consistently in Salt Lake City, nearly as high in Ogden and lowest in Magna and Kearns.

Annual mean suspended nitrate (SN) concentrations measured as water-soluble nitrates deposited on the high-volume filter were low (annual geometric means between 0.6 and 2.4 $\mu g/m^3$). However, during the months of December, January and February, 24-hr mean concentrations in excess of 15 $\mu g/m^3$ were measured with some regularity in all of the study areas, and the maximum 24-hr concentration for Ogden or for Salt Lake City was in the range of 50 $\mu g/m^3$.

Suspended sulfate levels also were low on the basis of annual means. Again, however, quarterly maxima and ninetieth percentile data indicate that, during the winter months, 24-hr mean levels in excess of 50 $\mu g/m^3$ were experienced in all areas

Table 1. Demographic characteristics of participants in studies of acute respiratory illness: Utah, 1971–1973.

Year		Crowding index[a]	Education[b] HS grad.	Education[b] Coll. grad.	Smokers, % Mothers	Smokers, % Fathers
1971–72	Ogden	30	79	13	16	25
	Salt Lake City	34	72	13	15	26
	Kearns	42	73	8	20	30
	Magna	37	79	10	19	31
1972–73	Ogden	34	82	15	15	30
	Salt Lake City	39	75	16	20	29
	Kearns	45	83	8	22	31
	Magna	38	82	11	30	33

[a]Percent of families with more than one person per room in their home.
[b]Percent of heads of households with the indicated minimal attainment.

except Ogden, where lowest exposure levels occurred consistently.

Demographics and Personal Characteristics of the Study Populations

The demographic data collected (Table 1) indicated that there were some differences in the study populations based on educational attainment, crowding, parental smoking and race. These differences were controlled by limiting the analyses to white subjects and by the multiple regression.

The number of families from whom information was obtained for at least half of the study periods varied among the study communities for the 1971-72 study period from about 240 to 280 (Table 2). During the second study year, the same families comprised the major segment of the study population. However, there were some losses and some new recruitments for the second year of the study. Overall, the total study population for the second year was about 10 percent smaller than was that for the first year.

Participation for each family segment in each study community exceeded 95.9 percent in each year of study.

Illness Frequency and Severity

The reliability of data obtained through the telephone interviews was checked by reinterviewing families containing 1272 individuals. Comparison of the data obtained with those provided on the original interview several days earlier gave a concordance (i.e., consistent information for the two interviews) in excess of 96% with a reported illness rate of approximately 15%.

Incidence rates for respiratory illness during the study periods (Table 3) showed no consistency with the SO_2 pollution concentrations among the various family segments or between the two years of study. Mean severity scores showed no consistent relationships with the community of residence nor did the percentage of the population who experienced either no illnesses or multiple illnesses.

Table 2. Number of participants in studies of acute respiratory illness: Utah, 1971–73.

Year		All families Ogden	All families Salt Lake City	All families Kearns	All families Magna	White stable families[a] Ogden	White stable families[a] Salt Lake City	White stable families[a] Kearns	White stable families[a] Magna
1971–72	Fathers	246	253	297	261	157	149	225	195
	Mothers	250	256	282	266	155	147	218	193
	School Children	433	453	574	577	265	252	442	437
	Preschool Children	156	180	245	206	89	84	188	157
	Totals	1085	1142	1380	1310	666	632	1073	982
1972–73	Fathers	222	230	240	251	137	131	199	187
	Mothers	221	225	246	258	135	133	196	194
	School Children	415	464	510	561	250	266	407	422
	Preschool Children	173	182	215	201	105	89	176	155
	Totals	1031	1101	1271	1271	627	619	978	958

[a]Stable families are those who have lived at the same address for at least 5 years.

Table 3. Illness rates per 100 weeks of observation in families exposed to different concentrations of air pollution: Utah, 1971–1973.

	1971–72 study[a]			1972–73 study		
	Upper	Lower	Total illness	Upper	Lower	Total illness
Fathers						
Ogden	2.72	1.18	3.90	2.93	0.91	3.83
S.L.C.	3.54	1.07	4.61	2.51	0.77	3.28
Kearns	3.26	1.24	4.50	3.13	1.00	4.13
Magna	3.28	1.02	4.32	2.67	0.99	3.66
Mothers						
Ogden	3.85	1.11	4.97	3.56	1.26	4.83
S.L.C.	4.95	0.96	5.92	4.80	1.06	5.86
Kearns	4.74	1.26	5.99	4.27	1.33	5.60
Magna	4.64	1.64	6.28	3.91	1.38	5.29
School Children						
Ogden	5.63	1.46	7.09	5.18	0.91	6.09
S.L.C.	6.36	1.58	7.95	5.99	0.76	6.75
Kearns	5.51	1.01	6.52	5.11	1.09	6.19
Magna	4.94	1.18	6.13	4.94	1.12	6.06
Preschool Children						
Ogden	7.35	2.36	9.72	7.40	1.96	9.35
S.L.C.	8.14	2.81	10.95	7.75	1.60	9.35
Kearns	7.77	2.21	9.97	6.67	1.79	8.45
Magna	8.55	2.05	10.62	7.58	2.17	9.75

[a] *t* tests of group differences for 1971–1972 gave $p = < 0.05$ for the following: (highest rate in italics) Fathers, upper, Ogden vs. *SLC*. Mothers, upper, Ogden vs. *SLC*, upper; Ogden vs. *Kearns;* all, Ogden vs. *Kearns;* lower, Ogden vs. *Magna;* all, Ogden vs. *Magna;* lower, *SLC* vs. *Magna*. Schoolchildren, lower, *Ogden* vs. Kearns; all, *Ogden* vs. Magna; upper, *SLC* vs. Kearns; lower, *SLC* vs. Kearns; all, *SLC* vs. Kearns; upper, *SLC* vs. Magna; lower, *SLC* vs. Magna; all, *SLC* vs. Magna.

[b] *t* tests of group differences for 1972–1973 gave $p < 0.05$ for the following: Mothers, upper, *Ogden* vs. SLC. Schoolchildren, upper, *SLC* vs. Kearns; lower, SLC vs. *Kearns;* upper, *SLC* vs. Magna; lower SLC vs. *Magna*.

Neither the average number of days of restricted activity associated with illness or the number of physician visits showed a consistent pattern with area of residence, within the family segments, or from year to year.

A stratified analysis showed that smoking was related fairly consistently in both adults and their children with higher rates of LRD but not with higher rates of URD.

A similar stratification gave some evidence that children of parents with chronic bronchitis were themselves subject to higher rates of respiratory illness but the data were far from conclusive.

The regression analysis (Tables 4 and 5) supported an inconsistent association of illness rates with smoking or bronchitis and in addition indicated the educational attainment of the head of household was frequently significant. However, once the effect of these factors was removed, the adjusted rates showed little association with community of residence (Table 6). Usually, when statistically significant differences in illness rates were observed, the higher rate occurred somewhere other than the designated high pollution area, Magna. Since inclusion of the potential interaction factors added very little to the analysis, they were not included in the adjustments presented in Tables 4-6.

Discussion

The results of this study suggest that neither the incidence nor the intensity of reported respiratory illness was affected by exposure to mean annual concentrations of SO_2 in the range of 12 to 50% above the present annual air quality standard of 80 $\mu g/m^3$.

The results leading to this conclusion, however, could have been affected by factors not controlled in this study but this is not believed to be likely. Possible confounders include the lack of independence among illness rates for the various family members and the possibility that factors used in the regression analyses may be multicollinear. The similarity of the relative risks of acquiring respiratory illness shown by the unadjusted rates in Table 3 and the adjusted rates in Table 5 suggests that the combined effect of the potential confounders was small.

The square-root transformation to develop a bet-

Table 4. Multiple linear regression rates of URD, LRD and total ARD on education, crowding, parental smoking, bronchitis in parents and residence among fathers, mothers, school children and preschool children: Utah 1971–1972 (white stable families only).

Main effect	df	F values		
		Upper	Lower	Total
Fathers				
Regression	7, 718	1.29	0.96	1.11
Education	1, 718	0.79	0.64	0.10
Crowding	1, 718	0.28	0.10	0.26
Smoking	1, 718	2.39	0.61	0.82
Bronchitis	1, 718	1.43	1.85	4.01[a]
Magna vs. Ogden	1, 718	2.78	0.58	0.58
Magna vs. SLC	1, 718	0.09	0.24	0.90
Magna vs. Kearns	1, 718	0.19	1.58	0.38
Mothers				
Regression	7, 705	2.99[a]	1.94	2.83[a]
Education	1, 705	4.97[a]	2.79	8.40[a]
Crowding	1, 705	0.19	0.96	1.51
Smoking	1, 705	4.01[a]	2.32	0.38
Bronchitis	1, 705	4.46[a]	0.42	4.47[a]
Magna vs. Ogden	1, 705	1.50	2.10	2.72
Magna vs. SLC	1, 705	3.02	5.15[a]	0.16
Magna vs. Kearns	1, 705	1.78	1.82	0.28
School children				
Regression	7, 1388	2.06[a]	4.47[a]	3.41[a]
Education	1, 1388	0.04	15.04[a]	2.96
Crowding	1, 1388	0.31	1.79	0.06
Smoking by parents	1, 1388	0.32	4.36[a]	0.03
Bronchitis in parents	1, 1388	3.37	0.00	4.00[a]
Magna vs. Ogden	1, 1388	3.27	1.02	4.08[a]
Magna vs. SLC	1, 1388	12.37[a]	4.49[a]	18.57[a]
Magna vs. Kearns	1, 1388	2.74	1.24	1.26
Preschool children				
Regression	7, 510	1.85	1.51	1.66
Education	1, 510	1.88	3.86[a]	4.59[a]
Crowding	1, 510	1.19	0.26	0.07
Smoking by parents	1, 510	2.92	2.35	0.49
Bronchitis in parents	1, 510	1.27	0.40	2.60
Magna vs. Ogden	1, 510	3.00	0.14	3.14
Magna vs. SLC	1, 510	0.40	3.10	0.16
Magna vs. Kearns	1, 510	3.14	0.48	2.60

[a]7 df: $p < 0.05$, $F \geqslant 2.03$; 1 df: $p < 0.05$, $F \geqslant 3.86$.

ter distribution of illness rates for analysis would not be a valid procedure if there was wide variation in the number of weeks of participation by individual study subjects. However, the overall participation of nearly 96% was adequate to permit use of the method.

This study is not entirely inconsistent with the earlier study of CRD in the same communities which found significant increases among smokers and nonsmokers of both sexes after 4 to 7 years residence in the designated high pollution area (*19*). The few historic aerometric data available from the area, indicate that, through the mid-1960s, the concentrations of particulate matter were 50% or more higher than they were in 1971, while the concentrations of SO_2 apparently varied less. It is possible therefore that the increased prevalence of adult CRD found in Magna in 1970 was due to prior extended exposure to higher concentration of both TSP and SO_2. More recent exposure to the same high SO_2 but lower TSP concentrations may not have been sufficient to produce higher rates of ARD. The prior higher concentration of both TSP and SO_2 might also have been the primary cause of increased illness rates found in the 1970 retrospective study of LRD in children (*15*).

Although the study results, in the opinion of the authors, suggest that SO_2 is a less significant pollu-

Table 5. *Multiple linear regression rates of URD, LRD and total ARD on education, crowding, parental smoking, bronchitis in parents and residence among fathers, mothers, school children and preschool children: Utah 1972–1973 (white stable families only).*

Main effect	df	*F* values		
		Upper	Lower	Total
Fathers				
Regression	7, 646	1.11	0.96	1.35
Education	1, 646	1.57	1.70	0.27
Crowding	1, 646	1.33	0.49	2.21
Smoking	1, 646	0.44	0.65	1.28
Bronchitis	1, 646	0.00	2.28	0.63
Magna vs. Ogden	1, 646	0.42	0.01	0.24
Magna vs. SLC	1, 646	0.52	1.46	1.80
Magna vs. Kearns	1, 646	1.69	0.01	0.85
Mothers				
Regression	7, 650	2.38[a]	1.11	1.02
Education	1, 650	0.17	0.29	0.34
Crowding	1, 650	4.95[a]	0.33	3.98[a]
Smoking	1, 650	4.01[a]	4.68[a]	0.36
Bronchitis	1, 650	0.03	0.76	0.25
Magna vs. Ogden	1, 650	0.81	0.04	0.44
Magna vs. SLC	1, 650	3.19	0.25	0.88
Magna vs. Kearns	1, 650	0.29	0.09	0.01
School children				
Regression	7, 1337	1.73	2.63[a]	1.31
Education	1, 1337	1.14	0.56	1.22
Crowding	1, 1337	1.27	2.16	2.75
Smoking by parents	1, 1337	0.75	6.63[a]	0.07
Bronchitis in parents	1, 1337	2.71	1.23	1.78
Magna vs. Ogden	1, 1337	0.56	1.40	0.02
Magna vs. SLC	1, 1337	7.53	2.66	3.14
Magna vs. Kearns	1, 1337	0.76	0.00	0.47
Preschool children				
Regression	7, 517	1.12	0.79	1.49
Education	1, 517	0.13	1.47	0.57
Crowding	1, 517	1.12	0.83	2.41
Smoking by parents	1, 517	0.01	0.37	0.30
Bronchitis in parents	1, 517	3.01	0.07	3.57
Magna vs. Ogden	1, 517	0.04	0.22	0.33
Magna vs. SLC	1, 517	0.00	3.16	1.02
Magna vs. Kearns	1, 517	2.42	1.38	4.62[a]

[a]7 df: $p < 0.05$, $F \geqslant 2.03$; 1 df: $p < 0.05$, $F \geqslant 3.86$.

tant than is TSP at the levels monitored during this study, it is not possible from the data collected to indicate safe or unsafe concentrations of either pollutant numerically. This is due to the inaccuracies associated with pollutant measurements; the inability to determine whether short-term or long-term exposure is the more important criterion; the lack of knowledge concerning possible interactions between a number of pollutants; the inability to associate individual exposures with the data collected at single stationary air pollution monitors; and the lack of information concerning the possible presence of other toxic air pollutants. For example, in two of the Utah study communities, the measurements of TSP were affected significantly by the proximity of a heavily traveled roadway to the air monitored stations. This would tend to overestimate TSP exposure in the quieter residential areas even though accurate measurements were made. In addition, it has been shown that the West-Gaeke method for collecting SO_2 is temperature-dependent (*20*), a fact that may have affected measurement in Utah very little during the winter months, but the total effect on annual means is unknown. Any effect would have tended to produce underestimations of acutal SO_2 exposures. For these reasons, the actual TSP exposures may have been even more similar in the four study communities than indicated in Figure, 1 and the

Table 6. Relative rates of ARD in families in Utah study areas adjusted for education, crowding, parental smoking, and bronchitis in parents and area of residence (white stable families only): 1971–1972 and 1972–1973.

Year		Upper	Lower	Total
1971–1972	Fathers			
	Ogden	0.83	1.18	0.94
	SLC	1.13	1.08	1.11
	Kearns	1.02	1.16	1.07
	Magna	1.00	1.00	1.00
	Mothers			
	Ogden	0.80	1.25	0.78
	SLC	1.14	0.64[a]	0.98
	Kearns	1.07	0.78	0.98
	Magna	1.00	1.00	1.00
	School children			
	Ogden	1.15	1.25	1.18
	SLC	1.29[a]	1.38[a]	1.32[a]
	Kearns	1.11	0.86	1.08
	Magna	1.00	1.00	1.00
	Preschool children			
	Ogden	0.80	1.06	0.88
	SLC	0.89	1.22	0.99
	Kearns	0.86	1.01	0.91
	Magna	1.00	1.00	1.00
1972–1973	Fathers			
	Ogden	1.11	0.97	1.06
	SLC	0.93	0.83	0.89
	Kearns	1.19	1.00	1.14
	Magna	1.00	1.00	1.00
	Mothers			
	Ogden	0.86	0.98	0.91
	SLC	1.27	0.86	1.12
	Kearns	1.10	0.99	1.06
	Magna	1.00	1.00	1.00
	School children			
	Ogden	1.06	0.88	1.02
	SLC	1.24	0.79	1.13
	Kearns	1.05	0.98	1.04
	Magna	1.00	1.00	1.00
	Preschool children			
	Ogden	0.93	0.90	0.93
	SLC	0.97	0.74	0.91
	Kearns	0.83	0.81	0.73[a]
	Magna	1.00	1.00	1.00

[a]Rate is significantly different ($p < 0.05$) when contrasted with Magna, the designated high pollution area.

annual mean SO_2 exposure, particularly in Magna, may have been higher than indicated in Figure 1.

Indoor pollution, particularly NO_2 associated with using a gas stove for cooking, has been shown in some areas to be associated with higher rates of respiratory illness (*21*). Such pollution may have been a significant factor in Utah but appropriate data for determining such significance were not collected. NO_2 also may have been an important ambient pollutant in this study, especially in the designated low pollution areas.

In conclusion, it is believed that the data support the hypothesis that SO_2 in high concentrations apparently had little or no effect on the incidence of acute respiratory illnesses in Utah.

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